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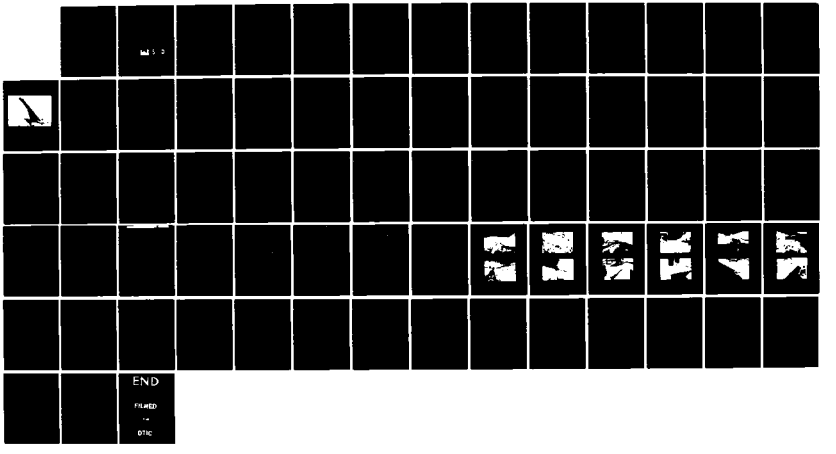

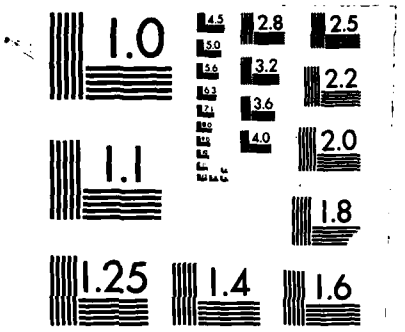

MICROCOPY RESOLUTION TEST CHART
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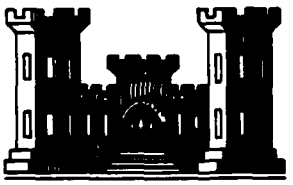
BLACKSTONE RIVER BASIN
HOLDEN, MASSACHUSETTS

HOLDEN RESERVOIR No 1 DAM

MA 00960

PHASE I INSPECTION REPORT

NATIONAL DAM INSPECTION PROGRAM



DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM MASS. 02154

JUNE, 1981

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

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		6. PERFORMING ORG. REPORT NUMBER
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Cover program reads: Phase I Inspection Report, National Dam Inspection Program; however, the official title of the program is: National Program for Inspection of Non-Federal Dams; use cover date for date of report.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

DAMS, INSPECTION, DAM SAFETY,

Blackstone River Basin
Holden Massachusetts
Tatnuck Brook

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The dam is an embankment structure with a stone masonry core wall. The dam is 770 ft. long and has a hydraulic height of 38 ft. The dam is considered to be in fair condition. The size is small and has a hazard potential of high. There are various remedial measures which should be implemented by the owner.

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
424 TRAPELO ROAD
WALTHAM, MASSACHUSETTS 02254

REPLY TO
ATTENTION OF:

AUG 18 1981

NEDED

Honorable Edward J. King
Governor of the Commonwealth of
Massachusetts
State House
Boston, Massachusetts

Dear Governor King:

Inclosed is a copy of the Holden Reservoir No. 1 Dam (MA-00960) Phase I Inspection Report, prepared under the National Program for Inspection of Non-Federal Dams. The report is based upon a visual inspection, a review of past performance, and a preliminary hydrological analysis.

The preliminary hydrologic analysis has indicated that the spillway capacity for the Holden Reservoir No. 1 Dam would likely be exceeded by floods greater than 30 percent of the Probable Maximum Flood (PMF). Our screening criteria specifies that a dam classified as high hazard with a spillway capacity insufficient to discharge fifty percent of the PMF be judged as having a seriously inadequate spillway. As a result this dam is assessed as unsafe, non-emergency until more detailed studies prove otherwise or corrective measures are completed.

The term "unsafe" applied to a dam because of an inadequate spillway does not indicate the same degree of emergency as it would if applied because of structural deficiency. It does indicate, however, that a severe storm may cause overtopping and possible failure of the dam, with significant damage and potential loss of life downstream.

We recommend that within twelve months from the date of this report the owner of the dam engage the services of a qualified registered engineer to determine further the potential of overtopping the dam and the need for and the means to increase project discharge capacity. Based on this determination, appropriate remedial mitigating measures should be designed and completed within 24 months of this date of notification. In the interim a detailed emergency operation plan and warning system should be promptly developed and round-the-clock surveillance should be provided during periods of heavy precipitation or high project discharge.

AUG 18 1981

NEDED
Honorable Edward J. King

I approve the report and support the findings and recommendations described in Section 7, with qualifications as noted above. I request that you keep me informed of the actions taken to implement these recommendations since this follow-up is an important part of the program.

Copies of this report have been forwarded to the Department of Environmental Quality Engineering and to the owner, City of Worcester, Water Operations, Worcester, MA. Copies will be available to the public in thirty days.

I wish to thank you and the Department of Environmental Quality Engineering for your cooperation in this program.

Sincerely,

WILLIAM E. HODGSON, JR.
Colonel, Corps of Engineers
Acting Commander and Division Engineer

HOLDEN RESERVOIR NO. 1 DAM

MA 00960

BLACKSTONE RIVER
HOLDEN, MASSACHUSETTS

PHASE I - INSPECTION REPORT
NATIONAL DAM INSPECTION PROGRAM

NATIONAL DAM INSPECTION PROGRAM
PHASE I - INSPECTION REPORT
BRIEF ASSESSMENT

Identification No.:	MA 00960
Name of Dam:	Holden Reservoir No. 1
City:	Holden
County and State:	Worcester County, Massachusetts
Stream:	Tatnuck Brook
Date of Inspection:	December 3, 1980

Holden Reservoir No. 1 Dam, owned and operated by the City of Worcester for the purpose of water supply, is located in the town of Holden, Massachusetts. The dam is an embankment structure with a stone-masonry core wall. The dam is 770 feet long and has a hydraulic height of 38 feet. The emergency spillway discharges directly into Holden Reservoir No. 2 and is located on the northeast side of the site.

As a result of the visual inspection and a review of available data, Holden Reservoir No. 1 Dam is considered to be in fair condition. Major concerns are: irregularity of the riprap on the upstream face of the dam; deterioration of the slush grout between the riprap stones; lack of grass cover and erosion protection on the crest of the dam; minor softness on the downstream slope; and the inability of the spillway to pass the test flood discharge.

The dam is classified as intermediate in size and a high hazard structure in accordance with the recommended guidelines established by the Corps of Engineers. The test flood for this dam equals the Probable Maximum Flood (PMF). Since the dam falls in the intermediate size range, the PMF was utilized for the hydrologic analysis. The test flood inflow was estimated to be 8,800 cubic feet per second (cfs) and resulted in an outflow discharge estimated to be 7,150 cfs, which would overtop the dam crest by about 1.7 feet. The maximum spillway capacity with the water level at the dam crest was estimated to be 2,061 cfs, which is about 30 percent of the test flood discharge. A major breach to the dam would increase the stage of Holden Reservoir No. 2 (which is immediately downstream of Holden Reservoir No. 1) by approximately 133 feet above the spillway crest of Holden Reservoir No. 2. Such a breach would cause Dawson Road to be overtopped by approximately 12.4 feet. It is estimated

that approximately 5 houses in the area would be affected. In addition, excessive damage to the earth embankment of Holden Reservoir No. 2 would be expected.

It is recommended that the City of Worcester engage a qualified registered professional engineer to specify and oversee repairs for the riprap and construction of adequate erosion protection for the crest of the dam. He should also investigate the cause of the softness on the downstream slope and design and oversee remedial construction, if needed. The engineer should perform a detailed hydrologic and hydraulic investigation to assess the potential of overtopping the dam and the need for and the means to increase project discharge capacity. The owner should repair and regrout mortar joints in the spillway training walls and replace rotted decking on the service bridge. A visual inspection of the dam should be made once a month and a comprehensive technical investigation made once a year. A surveillance program should be established for use during and after a heavy rainfall, and a downstream warning program developed.

The recommendations and remedial measures are described in Section 7 and should be addressed by the owner within one year after receipt of this Phase I Inspection Report.

Howard Sheavitz, P.E.
Project Manager
M.P.E. No. 28447

SCHOENFELD ASSOCIATES, INC.
Boston, Massachusetts

This Phase I Inspection Report on **Holden Reservoir No.1 Dam (MA-00960)** has been reviewed by the undersigned Review Board members. In our opinion, the reported findings, conclusions, and recommendations are consistent with the Recommended Guidelines for Safety Inspection of Dams, and with good engineering judgement and practice, and is hereby submitted for approval.

ARAMAST MAHTESIAN, MEMBER
Geotechnical Engineering Branch
Engineering Division

CARNEY M. TERZIAN, MEMBER
Design Branch
Engineering Division

JOSEPH W. FINEGAN, JR., CHAIRMAN
Water Control Branch
Engineering Division

APPROVAL RECOMMENDED:

JOE B. FRYAR
Chief, Engineering Division

PREFACE

This report is prepared under guidance contained in the Recommended Guidelines for Safety Inspection of Dams, for Phase I Investigations. Copies of these guidelines may be obtained from the Office of Chief of Engineers, Washington, D.C. 20314. The purpose of a Phase I Investigation is to identify expeditiously those dams which may pose hazards to human life or property. The assessment of the general condition of the dam is based upon available data and visual inspections. Detailed investigation and analysis involving topographic mapping, subsurface investigations, testing, and detailed computational evaluations are beyond the scope of a Phase I Investigation; however, the investigation is intended to identify any need for such studies.

In reviewing this report, it should be realized that the reported condition of the dam is based on observations of field conditions at the time of inspection along with data available to the inspection team. In cases where the reservoir was lowered or drained prior to inspection, such action, while improving the stability and safety of the dam, removes the normal load on the structure and may obscure certain conditions which might otherwise be detectable if inspected under the normal operating environment of the structure.

It is important to note that the condition of a dam depends on numerous and constantly changing internal and external conditions, and is evolutionary in nature. It would be incorrect to assume that the present condition of the dam will continue to represent the condition of the dam at some point in the future. Only through continued care and inspection can there be any chance that unsafe conditions be detected.

Phase I inspections are not intended to provide detailed hydrologic and hydraulic analyses. In accordance with the established guidelines, the Spillway Test Flood is based on the estimated "Probable Maximum Flood" for the region (greatest reasonably possible storm runoff), or fractions thereof. Because of the magnitude and rarity of such a storm event, a finding that a spillway will not pass the test flood should not be interpreted as necessarily posing a highly inadequate condition. The test flood provides a measure of relative spillway capacity and serves as an aide in determining the need for more detailed hydrologic and hydraulic studies, considering the size of the dam, its general condition, and the downstream damage potential.

The Phase I Investigation does <u>not</u> include an assessment of the need for fences, gates, no-trespassing signs, repairs to existing fences and railings, and other items which may be needed to minimize trespassing and provide greater security for the facility and safety to the public. An evaluation of the project for compliance with OSHA rules and regulations is also excluded.

HOLDEN RESERVOIR NO. 1 DAM

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REPORT

procedure for Estimating Effect of Surcharge Storage on Maximum Probable Discharge. The reservoir water surface was assumed to be at elevation 750.8 prior to the flood routing. The project discharge was estimated to be 7,150 cfs. This analysis indicated that the dam embankment crest would be overtopped by approximately 1.7 feet. The maximum spillway capacity with the water level at the dam crest was estimated to be 2,000 cfs, or about 28 percent of the test flood outflow. The 43-foot long emergency spillway to Holden Reservoir No. 2 does not have adequate capacity to handle the test flood discharge.

5.5 Dam Failure Analysis

The impact of dam failure with the reservoir surface at the dam crest was assessed utilizing the "Rule of Thumb" Guidance for Estimating Downstream Dam Failure Hydrographs provided by the Corps of Engineers. The analysis covered a reach extending approximately 1.1 mile downstream to a point where damage to residences on Dawson Road is indicated. Based on this analysis, Holden Reservoir No. 1 Dam was classified as a high hazard.

Antecedent flow of approximately 1,850 cfs prior to breach is negligible as compared to a breach outflow of 50,000 cfs. Therefore, absolute depths of flooding computed along downstream reaches can also be referred to as increases in stage due to breach.

A major breach to the dam would increase the stage at Holden Reservoir No. 2 immediately downstream of Holden Reservoir No. 1 to 13.3 feet above the spillway crest. The earth embankment at Holden Reservoir No. 2 would be overtopped by 7.3 feet, probably resulting in excessive damage. Further downstream, five inhabited structures on Dawson Road wuld be flooded. Two of these structures would be inundated by ten feet of water. Excessive property damage and loss of more than a few lives would probably occur.

SECTION 5
EVALUATION OF HYDROLOGIC/HYDRAULIC FEATURES

5.1 General

Holden Reservoir No. 1 Dam is an embankment structure with a stone-masonry core wall. According to design drawings, the dam is 770 feet long and has a maximum structural height of 48 feet. The spillway has a length of 43 feet. The spillway is located on the northeast side of the site. The rollway is 200 feet long and 43 feet wide. The side walls which form the channel are vertical. The crest is sand and gravel and covered with grass. The upstream slope is riprapped. The downstream slope has a sparse cover of course weeds.

The normal outlet is a 30-inch drain located on the northeast side of the reservoir and discharges to Holden Reservoir No. 2. The dam impounds Holden Reservoir No. 1, which forms a portion of the City of Worcester's water supply system.

5.2 Design Data

No hydrological or hydraulic design data were disclosed.

5.3 Experience Data

Daily readings of the water surface elevations for the period of operation are maintained by the Supervisor, Water Supply, City of Worcester. The records indicate that the highest surface elevation was 751.9 and occurred on August 19, 1955.

5.4 Test Flood Analysis

Due to the absence of detailed design and operational information, the hydrologic evaluation was performed utilizing field inspection data, watershed size, and an estimated test flood equal to the Probable Maximum Flood (PMF). The full PMF test flood was selected because of the high hazard of the dam and of its intermediate size. The Corps of Engineers "rolling" guide curve was used to compute inflow with consideration given to orographic, slope, and storage factors within the watershed.

Based on an estimated maximum probable flood peak flow rate of 1,875 cfs per square mile and a drainage area of 4.7 square miles, the test flood inflow was estimated to be 8,800 cfs. The test flood was routed through the dam in accordance with the Corps of Engineers

SECTION 4
OPERATIONAL AND MAINTENANCE PROCEDURES

4.1 Operational Procedures

a. General. Holden Reservoir No. 1 Dam impounds Holden Reservoir No. 1, which is part of the City of Worcester's water supply system. The reservoir stores water for both the low and high service distribution systems. Water for low service is drawn off via the low-level outlet. The high service system utilizes reservoir water via a 36 inch gravity line which feeds the Olean Street pump station in Worcester.

b. Description of Any Warning System in Effect. No written warning system or emergency preparedness system exists for the dam.

4.2 Maintenance Procedures

a. General. The owner, the City of Worcester, is responsible for maintenance of the dam. The grass on the downstream toe of the dam is mowed on a regular basis. The stand of pine trees beyond the downstream toe is maintained free of brush. The site is visited daily. There are no established procedures or manuals.

b. Operating Facilities. No formal maintenance procedures for the operating facilities were disclosed.

4.3 Evaluation

The current operational and maintenance procedures appear adequate to insure that normal problems can be remedied within a reasonable period of time. However, the dam and appurtenant structures should be visually inspected once a month with a comprehensive technical inspection made once a year. The owner should also establish a surveillance program for use during and immediately after heavy rainfalls. A downstream warning program to follow in case of emergency should also be developed.

c. Appurtenant Structures. The spillway is 34 feet long and approximately 5 feet below the top of the dam. The spillway weir and training walls are in good condition (Photo No. 4). The last half of the concrete spillway channel floor, however, is in poor condition. It is severely cracked and heaved with significant spalling (Photo Nos. 5-7). A 30-inch low-level outlet pipe is laid in masonry in a trench (Photo No. 8). The locations of the gatehouse is downstream of the crest of the dam. As a result, the low-level outlet is under pressure through the dam whenever the water level is above the crown of the outlet. Piping problems relating to exfiltration from the low-level outlet material within the embankment may occur at some time.

The exterior of the gatehouse is in good condition. The interior floor is in poor condition, being severely cracked and of questionable structural integrity. Gate valves were reported operable by the owner although their condition is rather poor.

A concrete arch walkway spans the spillway at the spillway weir (Photo No. 9). It appears to be in good condition, but some minor spalling was noted (Photo Nos. 10 and 11).

d. Reservoir. No evidence of significant sedimentation in the reservoir was observed. The banks of the reservoir are well-maintained and are clear of trees and brush.

The area immediately adjacent to the pond is moderately sloped and well vegetated with brush and trees. The shoreline shows no sign of sloughing or erosion. A rapid rise in the water level of the pond would not endanger life or property.

e. Downstream Channel. The downstream channel is a natural channel of rock and gravel. The area adjacent to it is overgrown with brush and trees.

There is a low, stone-masonry training wall on the right side of the downstream channel immediately downstream of the chute spillway. This wall is in good condition. Weepholes at the bottom of the wall are open but no water was discharging from them at the time of the inspection. Both banks of the spillway channel are maintained free of trees and brush (Photo No. 12).

3.2 Evaluation

Overall the general condition of the Kettle Brook Reservoir No. 3 Dam is judged to be fair. The visual inspection revealed items that lead to this assessment, such as:

(1) Spalling, cracking, and heaving of spillway channel floor.

(2) Poor condition of interior of gate house.

SECTION 3
VISUAL INSPECTION

3.1 Findings

a. General. The visual inspection of Holden Reservoir No. 1 Dam was conducted on December 3, 1980. The field inspection team consisted of personnel from Schoenfeld Associates, Inc., D. Baugh Associates, Inc., and Geotechnical Engineers, Inc. Inspection checklists, completed during the field site visit, are included in Appendix A.

The structural condition of the dam and its appurtenant structures is fair.

b. Dam. The top of the dam is sand and gravel and is covered with grass which has been mowed. However, the grass cover is sparse in the center of the crest where vehicles have been driven from the right abutment to the spillway at the left abutment (Photo No. 1).

The upstream slope of the dam is covered with riprap from an elevation about 3 feet below the crest to some elevation (which cannot be determined from the visual inspection alone) below the reservoir level at the time of the inspection. The riprap has a maximum size of about 1-1/2 feet and the surface is rather irregular in the range of unusual water levels (Photo No. 2). Slush grout between the individual riprap stones on the upper part of the slope (apparently above the maximum reservoir level) is extensively cracked (Photo No. 3). Below the apparent maximum reservoir level, there is no slush grout between the riprap stones.

The downstream slope has a sparse cover of coarse weeds which has not been mowed, except along the bottom 10 to 15 feet of the slope which appears to have been mowed with a horse-drawn mower (Photo No. 4). Although no evidence of active seepage from the downstream slope was observed, some of the lower part of the slope was slightly soft and appeared to be indented with hoof-marks made by horses. The soft area is located from 300 feet to 350 feet from the left abutment and starts at the downstream toe of the slope and goes up the slope for approximately 15 feet.

A zone about 20 feet wide at the downstream toe is covered with grass which has been mowed and downstream of that zone there is a stand of pine trees which is maintained free of underbrush and can be inspected thoroughly (Photo No. 4). There is no sign of seepage in this area.

Both abutments of the dam appear to consist of soil at the ground surface (Photo No. 5). No evidence of seepage from the abutments was observed.

SECTION 2
ENGINEERING DATA

2.1 Design

A design drawing dated January 19, 1892 for Holden Reservoir No. 1 Dam was prepared by the Worcester County Engineering Department. No other information was available.

2.2 Construction

No construction records were available for use in evaluating the dam. The original dam was constructed in 1883 by some local manufacturers and was later incorporated as part of the present dam. This dam was constructed in 1911 by Worcester County for the City of Worcester.

2.3 Operation

No engineering operation data were available.

2.4 Evaluation

a. Availability. The engineering data used in the preparation of this report are presented in Appendix B.

b. Adequacy. Available engineering data and design drawings are considered adequate for a Phase I investigation.

c. Validity. The field investigation indicated that the external features of the present Holden Reservoir No. 1 Dam have not changed substantially from the design drawing of 1892.

h. Diversion and Regulating Tunnel - N/A

i. Spillway

(1) Type - broad-crested

(2) Length of weir - 43 feet

(3) Crest elevation - 750.8

(4) Gates - none

(5) U/S channel - concrete channel approximately 15 feet long leading to weir crest

(6) D/S channel - 260-foot long rollway; concrete channel with stone-masonry walls

(7) General - discharges directly into upper end of Holden Reservoir No. 2

j. Regulating Outlet

(1) Invert - 722.3

(2) Size - 30 inches

(3) Description - see below

(4) Control mechanism - gate valve located in control tower adjacent to spillway

(5) Other - none

(4) Test flood pool - 6,700

(5) Top of dam - 6,600

e. Storage (gross acre-feet)

(1) Normal pool - 2,250

(2) Flood control pool - N/A

(3) Spillway crest pool - 2,100

(4) Test flood pool - 3,000

(5) Top of dam - 2,800

f. Reservoir Surface (acres)

(1) Normal pool - 132

(2) Flood control pool - N/A

(3) Spillway crest pool - 126

(4) Test flood pool - 158

(5) Top of dam - 148

g. Dam

(1) Type - embankment structure with stone-masonry core wall

(2) Length - 770 feet

(3) Hydraulic height - 38 feet

(4) Top width - 25 feet

(5) Side slopes - 2:1 H:V on both faces

(6) Zoning - original dam and puddled earth on upstream face of core wall; rolled earth layers on downstream face

(7) Impervious core - stone-masonry

(8) Cutoff - unknown

(9) Grout curtain - unknown

(10) Other - none

(3) The spillway capacity with the water surface at the top of the dam is approximately 2,000 cfs at elevation 755.8.

(4) The spillway capacity with the water surface elevation at the test flood elevation of 757.5 is approximately 2,950 cfs. There are no provisions for flashboards.

(5) The spillway capacity at normal pool elevation (752.0) is 500 cfs. There are no provisions for flashboards.

(6) The spillway capacity at the test flood elevation (757.5) is 2,950 cfs.

(7) The total spillway capacity at the test flood elevation (757.5) is 2,950 cfs. There are no provisions for flashboards.

(8) The total project discharge at the top of the dam (755.8) is 2,000 cfs. There are no provisions for flashboards.

(9) The total project discharge at the test flood elevation of 757.5 is approximately 7,150 cfs.

c. Elevation (feet NGVD)

(1) Streambed at centerline of dam - 720 (estimated)

(2) Bottom of cutoff - 707 (estimated)

(3) Maximum tailwater - 720.1 (August 19, 1955)

(4) Normal pool - 752.0 (from U.S.G.S. quadrangle sheet)

(5) Full flood control pool - N/A

(6) Emergency spillway crest - 750.8

(7) Design surcharge - unknown

(8) Test flood surcharge - 757.5

(9) Top of dam - 755.8

d. Reservoir (length in feet)

(1) Normal pool - 6,500

(2) Flood control pool - N/A

(3) Spillway crest pool - 6,400

g. Purpose of Dam. The dam impounds water in Holden Reservoir No. 1, which is part of the City of Worcester's water supply system.

h. Design and Construction History. The original dam at this site was constructed in 1883 by some local manufacturers. This dam was a stone-masonry structure with a puddled earth blanket on the upstream slope and a stone-masonry cutoff wall into the foundation close to the upstream toe of the puddled earth.

In 1911, the dam was raised as an embankment structure which incorporated the original stone-masonry dam as the upstream section of the upstream slope of the new dam. This new dam had a stone-masonry core with puddled earth on the upstream side and layers of rolled earth on the downstream side. The dam was constructed by Worcester County for the City of Worcester.

i. Normal Operation Procedures. Holden Reservoir No. 1 stores water for both the low and high service distribution systems serving the City of Worcester, Massachusetts. Water for low service is drawn off via the low-level outlet. The high service system utilizes reservoir water via a 36 inch gravity line which feeds the Olean Street pump station in Worcester.

1.3 Pertinent Data

a. Drainage Area. The area tributary to the Holden Reservoir No. 1 Dam consists of 3,000 acres (4.7 square miles) of rolling terrain. There is no development in the watershed which attains a maximum elevation of about 1,395 feet. Reservoir full elevation is at 755.8 feet.

The area around the reservoir is mostly wooded. There are no cottages or dwellings along the shoreline.

b. Discharge at Dam Site

(1) Outlet works for Holden Reservoir No. 1 Dam consist of a 30-inch outlet pipe and a 43-foot long emergency spillway. The 260-foot long rollway is 43 feet wide and discharges to Tatnuck Brook. The invert of the outlet is at 722.3 feet. Maximum discharge of the pipe (137 cfs at elevation 755.8) is considered negligible when a comparison is made with the other flows evaluated. The emergency spillway has a crest at elevation 750.8. When the water surface is at the top of dam (elevation 755.8), the emergency spillway will have a capacity of 2,000 cfs.

(2) Daily records of maximum discharge have been maintained at the site. The maximum recorded elevation was 751.9 on August 19, 1955. It is believed that the dam has never been overtopped.

b. Description of Dam and Appurtenances. Holden Reservoir No. 1 Dam is an embankment structure with a stone-masonry core wall that is 4 feet wide at the top, which is approximately 2 feet below the crest, and 7 feet wide at the bottom, where it appears to be keyed 10 feet into the foundation. The dam is approximately 770 feet long with a maximum structural height of 48 feet. The crest of the dam is 25 feet wide and consists of sand and gravel covered with grass. The upstream slope of the dam is covered with riprap which extends from 3 feet below the crest to beneath the reservoir level. The riprap has a maximum size of about 1-1/2 feet and the surface is irregular in the range of usual water levels. The downstream slope has a sparse grass cover. Both faces of the dam slope at 2H:1V.

According to the plans, the present dam incorporates the original stone-masonry dam constructed in 1883 as the upstream section of the upstream slope. The material between the old dam and the new core wall is puddled earth. The embankment downstream of the new core wall consists of six layers of rolled earth.

Appurtenant structures include a 43-foot long emergency spillway and a 260-foot long rollway. The rollway is lined with concrete and has masonry training walls. The gatehouse for the 30-inch low-level outlet is a concrete structure with a masonry foundation. A service bridge provides access to the gatehouse from the dam embankment. The bridge, of steel construction supported by an intermediate concrete pier has a wooden deck. There is a 30-inch pipe under the dam which acts as the low-level outlet.

c. Size Classification. The dam is considered to be intermediate in size because the hydraulic height is 38 feet and the storage is 2,800 acre-feet. This is in accordance with the Recommended Guidelines for Safety Inspections for Dams, which defines an intermediate dam as having a storage capacity of 1,000 to 50,000 acre-feet.

d. Hazard Classification. The potential for hazard posed by this dam is classified as high. This is in accordance with the Recommended Guidelines for Safety Inspection for Dams, which defines a high hazard structure as one which poses a threat to more than a few lives. The earth embankment at Holden Reservoir No. 2 would be overtopped by 7.3 feet, probably resulting in excessive damage. Further downstream, five inhabited structures on Dawson Road would be flooded. Two of these structures would be inundated by ten feet of water. Excessive property damage and loss of more than a few lives would probably occur.

e. Ownership. The dam is owned by the City of Worcester.

f. Operator. The operation, maintenance, and safety of the dam is the responsibility of the City of Worcester, Water Operations. The Supervisor of Water Supply is Mr. Kenneth Starbard. His address is South Road, Holden, Massachusetts 01520. His telephone number is (617) 829-4811.

NATIONAL DAM INSPECTION PROGRAM
PHASE I - INSPECTION REPORT
HOLDEN RESERVOIR NO. 1

SECTION 1
PROJECT INFORMATION

1.1 General

a. Authority. Public Law 92-367, August 8, 1972, authorized the Secretary of the Army, through the Corps of Engineers, to initiate a National Program of Dam Inspection throughout the United States. The New England Division of the Corps of Engineers has been assigned the responsibility of supervising the inspection of dams within the New England Region. Schoenfeld Associates, Inc. has been retained by the New England Division to inspect and report on selected dams in the Commonwealth of Massachusetts. Authorization and notice to proceed were issued to Schoenfeld Associates, Inc. under a letter of October 30, 1980 from Colonel William E. Hodgson, Jr., Deputy Division Engineer. Contract No. DACW33-81-C-0010 has been assigned by the Corps of Engineers for this work.

b. Purpose

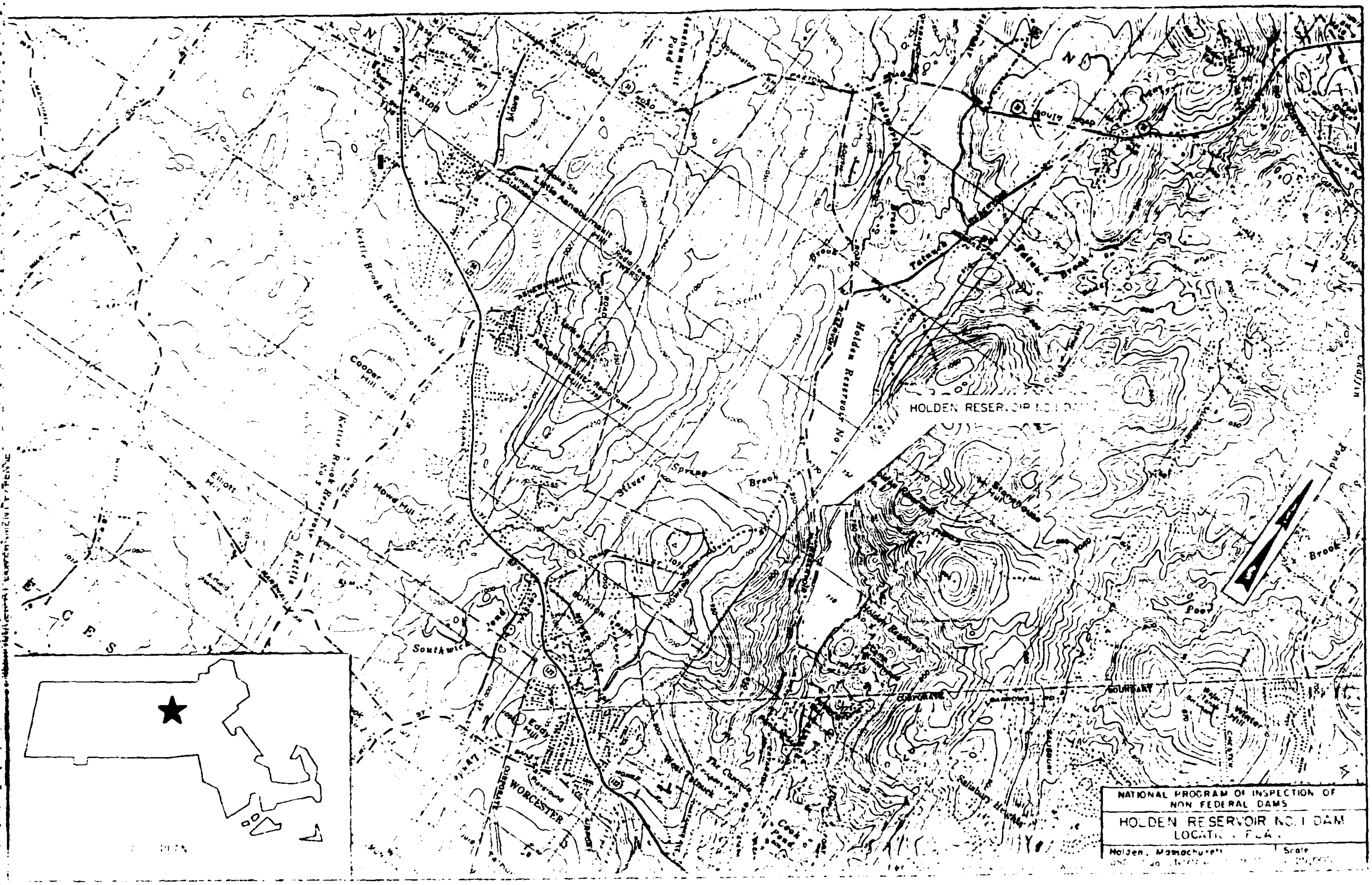
(1) To perform technical inspection and evaluation of nonfederal dams to identify conditions which threaten the public safety and thus permit correction in a timely manner by nonfederal interests.

(2) To encourage and prepare the states to initiate quickly effective dam safety programs for nonfederal dams.

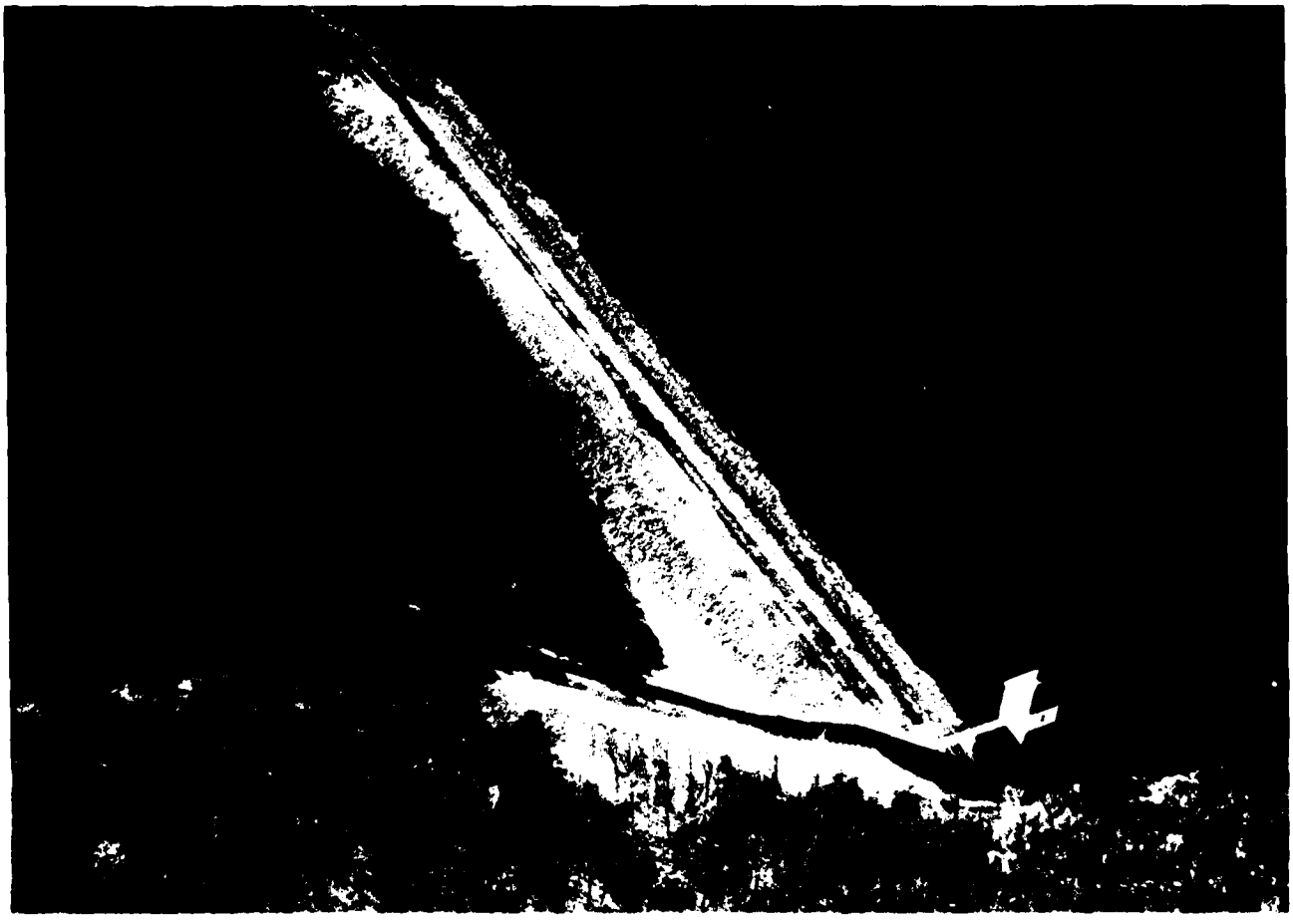
(3) To update, verify, and complete the National Inventory of Dams.

1.2 Description of Project

a. Location. Holden Reservoir No. 1 Dam is located in the southern portion of the town of Holden, Massachusetts on Tatnuck Brook, approximately 0.8 miles upstream of Holden Reservoir No. 2 Dam. The dam discharges directly into the upper end of Holden Reservoir No. 2. The dam is shown on the U.S.G.S. quadrangle sheet of Worcester North, Massachusetts. Its approximate coordinates are N42°-18'-24" and W71°-52'-74". The location of the dam is shown on the preceeding page.



NATIONAL PROGRAM OF INSPECTION OF NON FEDERAL DAMS
HOLDEN RESERVOIR NO. 1 DAM
HOLDEN RESERVOIR NO. 1 DAM
Holden Reservoir No 1
Paxton
WORCESTER
Little Asnebumskit Hill
Asnebumskit Hill
Kettle Brook Reservoir No 4
Kettle Brook Reservoir No 3
Cooper Hill
Howe Hill
Elliott Hill
Eddy Hill
Southwick
Salisbury Heights
Winter Hill
Chaffin
Brook
Pond



OVERVIEW PHOTOGRAPHY
HOLDEN RESERVOIR NO. 1 DAM

SECTION 6
EVALUATION OF STRUCTURAL STABILITY

6.1 Visual Observations

The general structural stability of the dam is good as evidenced by its alignment and structural condition. The dam, spillway, gatehouse, and service bridge are all in fair condition. The following conditions observed during the visual inspection, however, are indicative of problems that could result in long-term structural instability.

(1) Some irregularity of the riprap on the upstream face of the dam and some cracking and deterioration of the slush grout between the riprap stones in the upper part of the riprap is evidence of deterioration of the riprap, which should be controlled so as to prevent erosion of the embankment fill.

(2) The lack of grass cover in the wheel tracks on the crest of the dam increases the susceptibility of the crest to erosion in case the dam should be overtopped.

(3) Minor softness on some of the lower parts of the downstream slope may be indicative of a seepage problem which could become worse and might possibly lead to a piping problem.

In general, the dam, abutments, and downstream toe areas appear to be well-maintained.

6.2 Design and Construction Data

The original dam at this site was constructed in 1883 by local manufacturers. This dam was a stone-masonry structure with a puddled earth blanket on the upstream slope and a stone-masonry cutoff wall into the foundation close to the upstream toe of the puddled earth.

According to a design drawing of January 19, 1892, the dam was later raised as an embankment structure which incorporated the original stone-masonry dam as the upstream section of the upstream slope of the new dam. The new dam had a stone-masonry core with puddled earth on the upstream side and layers of rolled earth on the downstream side. The dam was constructed in 1911 by Worcester County for the City of Worcester.

6.3 Post-Construction Changes

A drawing dated January 19, 1892 and traced February 27, 1936 indicates that the original dam at this site was a stone-masonry dam with a puddled earth blanket, constructed in 1883, on the upstream slope of the stone-masonry structure, and with a stone-masonry cutoff wall into the foundation close to the upstream toe of the puddled earth.

This drawing also shows that the dam was later raised as an embankment dam which incorporated the old stone-masonry dam as the upstream section of the upstream slope of the new dam. The drawing indicates that the new dam has a stone-masonry core wall, 4 feet wide at the top (which is about 2 feet below the crest) and 7 feet wide at the bottom where it appears to be keyed 10 feet into the foundation. There is no information on the drawing concerning the nature of the foundation material. The material between the new core wall and the old dam, on the upstream side of the new core wall, is designated "puddled earth." The embankment downstream of the new core wall is designated "rolled earth - 6" layers." No other information is available.

6.4 Seismic Stability

This dam is in the boundary region between Seismic Zones 2 and, in accordance with the Phase I guidelines, does not warrant seismic analysis.

SECTION 7
ASSESSMENT, RECOMMENDATIONS, AND REMEDIAL MEASURES

7.1 Dam Assessment

a. Condition. After consideration of the available information, the results of the inspection, and contact with the owner, the structural condition of Holden Reservoir No. 1 Dam is judged to be in fair condition. The following conditions may lead to long-term problems.

(1) Some irregularity of the riprap on the upstream face of the dam and some cracking and deterioration of the slush grout between the riprap stones in the upper part of the riprap is evidence of deterioration of the riprap, which should be controlled so as to prevent erosion of the embankment fill.

(2) The lack of grass cover in the wheel tracks on the crest of the dam increases the susceptibility of the crest to erosion in case the dam should be overtopped.

(3) Minor softness on some of the lower parts of the downstream slope may be indicative of a seepage problem which could become worse and might possibly lead to a piping problem.

(4) The spillway is adequate to carry only 28 percent of test flood discharge.

b. Adequacy of Information. The information obtained from one design drawing and the results of the visual inspection are adequate for the purposes of this Phase I study.

c. Urgency. The owner should implement the recommendations in 7.2 and 7.3 within one year after receipt of this Phase I report.

7.2 Recommendations

The following investigations should be carried out and needed corrections performed under the direction of a registered professional engineer qualified in the design and construction of dams:

(1) Specify and oversee repairs for the riprap on the upstream slope.

(2) Specify and oversee construction of adequate erosion protection for the crest of the dam.

(3) Investigate the cause of softness on some of the lower parts of the downstream slope, design remedial construction if needed, and oversee remedial construction.

(4) Perform a detailed hydrologic and hydraulic investigation to assess for the potential of overtopping the dam and the need for and the means to increase project discharge capacity.

7.3 Remedial Measures

a. Operating and Maintenance Procedures. The owner should:

(1) Repair and regrout mortar joints in the spillway training walls.

(2) Replace rotted decking on the service bridge.

(3) Visually inspect the dam and appurtenant structures once a month.

(4) Engage a registered professional engineer qualified in the design and construction of dams to make a comprehensive technical inspection of the dam once every year.

(5) Establish a surveillance program for use during and immediately after heavy rainfall and also a downstream warning program to follow in case of emergency.

7.4 Alternatives

There are no practical alternatives to the recommendations and remedial measures described in Section 7.3.

APPENDIX A

INSPECTION CHECK LIST

VISUAL INSPECTION CHECKLIST
PARTY ORGANIZATION

PROJECT Holden Res. No. 1 Dam, MA

DATE Dec. 3, 1980

TIME 12:00

WEATHER Sunny, Cold, Windy

W.S. ELEV. 746.9 UPSTREAM
_____ DOWNSTREAM

PARTY:

1. Peter Palmieri, SAI
2. Michael Haire, DBA
3. Ronald Hirschfeld, GEI
4. _____
5. _____
6. _____
7. _____
8. _____
9. _____
10. _____

	PROJECT FEATURE	INSPECTED BY	REMARKS
1.	Hydrology/Hydraulics	Peter Palmieri	
2.	Structural Stability	Michael Haire	
3.	Soils and Geology	Ronald Hirschfeld	
4.			
5.			
6.			
7.			
8.			
9.			
10.			

PERIODIC INSPECTION CHECKLIST

PROJECT Holden Res. No. 1 Dam, MA DATE Dec. 3, 1980

PROJECT FEATURE Dam Embankment NAME _____

DISCIPLINE _____ NAME _____

AREA EVALUATED	CONDITION
DAM EMBANKMENT	
Crest Elevation	755.8
Current Pool Elevation	746.9
Maximum Impoundment to Date	751.9 (August 19, 1955)
Surface Cracks	None observed
Pavement Condition	Not paved
Movement or Settlement of Crest	None observed
Lateral Movement	None observed
Vertical Alignment	Good
Horizontal Alignment	Good
Condition at Abutment and at Concrete Structures	Good
Indications of Movement of Structural Items on Slopes	None observed
Trespassing on Slopes	No evidence of trespassing observed
Sloughing or Erosion of Slopes or Abutments	None observed
Rock Slope Protection - Riprap Failures	Riprap on upstream slope is somewhat irregular, slush grout is cracked between most riprap stones
Unusual Movement or Cracking at or Near Toe	None observed
Unusual Embankment or Downstream Seepage	None observed
Piping or Boils	None observed
Foundation Drainage Features	None observed
Toe Drains	None observed
Instrumentation System	None observed
Vegetation	Grass (mowed) on crest; grass & weeds (Unmowed) on downstream slope

PERIODIC INSPECTION CHECKLIST

PROJECT Holden Res. No. 1 Dam, MA DATE Dec. 3, 1980

PROJECT FEATURE Dike Embankment NAME _____

DISCIPLINE _____ NAME _____

AREA EVALUATED	CONDITION
DIKE EMBANKMENT	No dike
Crest Elevation	
Current Pool Elevation	
Maximum Impoundment to Date	
Surface Cracks	
Pavement Condition	
Movement or Settlement of Crest	
Lateral Movement	
Vertical Alignment	
Horizontal Alignment	
Condition at Abutment and at Concrete Structures	
Indications of Movement of Structural Items on Slopes	
Trespassing on Slopes	
Sloughing or Erosion of Slopes or Abutments	
Rock Slope Protection - Riprap Failures	
Unusual Movement or Cracking at or Near Toe	
Unusual Embankment or Downstream Seepage	
Piping or Boils	
Foundation Drainage Features	
Toe Drains	
Instrumentation System	
Vegetation	

PERIODIC INSPECTION CHECKLIST

PROJECT Holden Res. No. 1 Dam, MA DATE Dec. 3, 1980

PROJECT FEATURE Intake Channel NAME

DISCIPLINE NAME

AREA EVALUATED	CONDITION
OUTLET WORKS - INTAKE CHANNEL AND INTAKE STRUCTURE	
a. Approach Channel	
Slope Conditions	Good
Bottom Conditions	Not visible beneath reservoir pool
Rock Slides or Falls	None
Log Boom	None
Debris	None
Condition of Concrete Lining	Not applicable
Drains or Weep Holes	Not applicable
b. Intake Structure	
Condition of Concrete	Good
Stop Logs and Slots	None

PERIODIC INSPECTION CHECKLIST

PROJECT Holden Res. No. 1 Dam, MA DATE Dec. 3, 1980

PROJECT FEATURE Control Tower NAME

DISCIPLINE NAME

AREA EVALUATED	CONDITION
OUTLET WORKS - CONTROL TOWER	
a. Concrete and Structural	Masonry Construction
General Condition	Good
Condition of Joints	Good
Spalling	None
Visible Reinforcing	Not applicable
Rusting or Staining of Concrete	Not applicable
Any Seepage or Efflorescence	Not applicable
Joint Alignment	Good
Unusual Seepage or Leaks in Gate Chamber	None
Cracks	
Rusting or Corrosion of Steel	
b. Mechanical and Electrical	Not applicable
Air Vents	
Float Wells	
Crane Hoist	
Elevator	
Hydraulic System	
Service Gates	
Emergency Gates	
Lightning Protection System	
Emergency Power System	
Wiring and Lighting System	

PERIODIC INSPECTION CHECKLIST

PROJECT Holden Res. No. 1 Dam, MA DATE Dec. 3, 1980

PROJECT FEATURE Transition & Conduit NAME

DISCIPLINE NAME

AREA EVALUATED	CONDITION
OUTLET WORKS - TRANSITION AND CONDUIT	Not applicable
General Condition of Concrete	
Rust or Staining on Concrete	
Spalling	
Erosion or Cavitation	
Cracking	
Alignment of Monoliths	
Alignment of Joints	
Numbering of Monoliths	

PERIODIC INSPECTION CHECKLIST

PROJECT Holden Res. No. 1 Dam, MA DATE Dec. 3, 1980

PROJECT FEATURE Outlet Structure NAME

DISCIPLINE NAME

AREA EVALUATED	CONDITION
OUTLET WORKS - OUTLET STRUCTURE AND OUTLET CHANNEL	Block Masonry
General Condition of Concrete	Good
Rust or Staining on Concrete	None
Spalling	None on concrete; some masonry on training walls needs to be regrouted
Erosion or Cavitation	None
Visible Reinforcing	None
Any Seepage or Efflorescence	None
Condition at Joints	Good
Drain Holes	Not applicable
Channel	
Loose Rock or Trees Overhanging Channel	None observed
Condition of Discharge Channel	Good

PERIODIC INSPECTION CHECKLIST

PROJECT Holden Res. No. 1 Dam, MA DATE Dec. 3, 1980

PROJECT FEATURE Spillway Weir NAME

DISCIPLINE NAME

AREA EVALUATED	CONDITION
OUTLET WORKS - SPILLWAY WEIR, APPROACH AND DISCHARGE CHANNELS	
a. Approach Channel	
General Condition	Good
Loose Rock Overhanging Channel	None observed
Trees Overhanging Channel	None observed
Floor of Approach Channel	Boulders
b. Weir and Training Walls	
General Condition of Concrete	Good
Rust or Staining	None
Spalling	None
Any Visible Reinforcing	None
Any Seepage or Efflorescence	None
Drain Holes	Appear to be open, no discharge
c. Discharge Channel	
General Condition	Good
Loose Rock Overhanging Channel	None observed
Trees Overhanging Channel	None observed
Floor of Channel	Slush concrete
Other Obstructions	None observed
Other Comments	

PERIODIC INSPECTION CHECKLIST

PROJECT Holden Res. No. 1 Dam, MA DATE Dec. 3, 1980

PROJECT FEATURE Service Bridge NAME

DISCIPLINE NAME

AREA EVALUATED	CONDITION
OUTLET WORKS - SERVICE BRIDGE	
a. Super Structure	Good
Bearings	Good
Anchor Bolts	Good
Bridge Seat	Good
Longitudinal Members	Good
Underside of Deck	Good
Secondary Bracing	Good
Deck	Fair; wood planking has rotted
Drainage System	Not applicable
Railings	Good
Expansion Joints	None
Paint	Good
b. Abutment & Piers	Not applicable
General Condition of Concrete	
Alignment of Abutment	
Approach to Bridge	
Condition of Seat & Backwall	

Photo No. 11 - Rollway looking upstream.

Photo No. 12 - Rollway looking downstream into Holden Reservoir No. 2.

Photo No. 9 - Rollway steps; looking upstream.

Photo No. 10 - Upper end of rollway at base of steps.

Photo No. 7 - View upstream from crest of spillway weir.

Photo No. 8 - Gatehouse as viewed from left abutment of spillway.

Photo No. 5 - Left abutment.

Photo No. 6 - Entrance to spillway at left of dam.

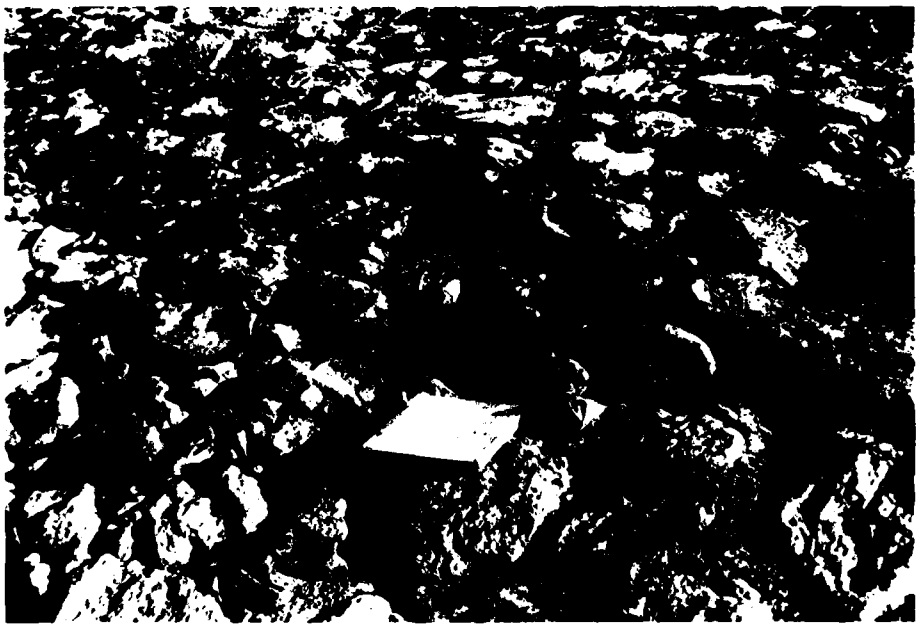


Photo No. 3 - Detail of cracked slush grouting.

Photo No. 4 - Downstream toe area.

Photo No. 1 - Crest of dam viewed from right abutment. Mowed grass on crest but relatively bare of vegetation in wheel tracks.

Photo No. 2 - Detail of riprap on upstream slope. Riprap is slush-grouted down to approximately normal water level. Grout is cracked around most riprap stones. Apparent wave-cut terrace just above present water level. Riprap shows signs of irregular subsidence or sloughing.

APPENDIX C

SELECTED PHOTOGRAPHS

(Index to Photographs is Found in Appendix B)

TOWN Holden DAM NO. 31-09

LOCATION Northeasterly side - Reservoir #1 STREAM Tatnuck Brook

Reservoir #1

WORCESTER COUNTY ENGINEERING DEPARTMENT
WORCESTER, MASSACHUSETTS

DAM INSPECTION REPORT

Owned by City of Worcester Place Water Dept. Use Water Supply.

Inspected by wgk Date June 22, 1965

Type of Dam Earth and granite stone Condition Good

SPILLWAY

Flashboards in Place No boards Recent Repairs

Condition Good. The abutment walls are concrete stone - this

Repairs Needed spillway is 5' high. The walled outlet channel is very steep.

EMBANKMENT

Recent Repairs

Condition Good condition. The reservoir is full to the spillway crest.

Repairs Needed

GATES

Recent Repairs

Condition The wood and granite stone gate house is locked.

Repairs Needed The pipe outlet is 20' below this gate at the lower reservoir - it is open.

LEAKS

How Serious

DATE: County Engineer

Haldan — Reservoir # — 21-03

Mar 14, 1969 (PPP) — Reservoir #3

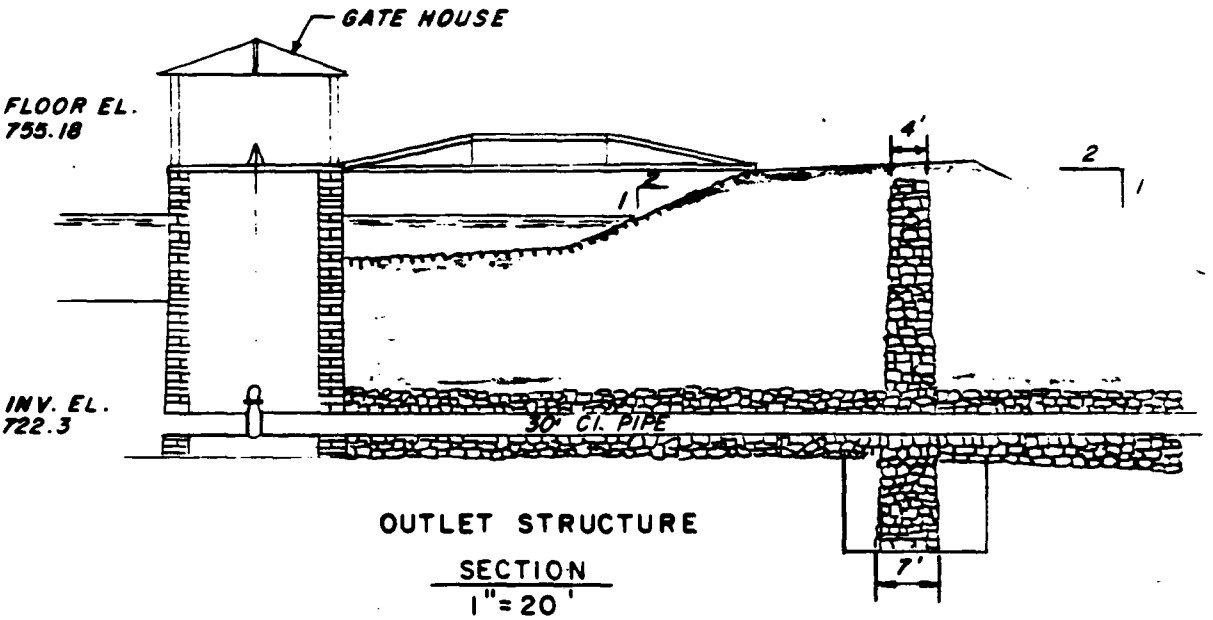
Owned by the City of Worcester - Water Dept.

Flood patrol — Good condition

No flashboards

No gate

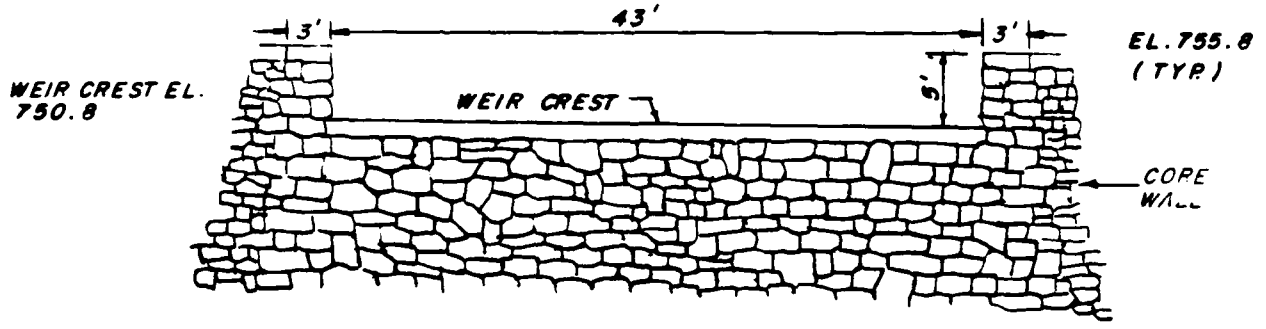
The pond is full to the spillway crest.



OUTLET STRUCTURE

SECTION

1" = 20'

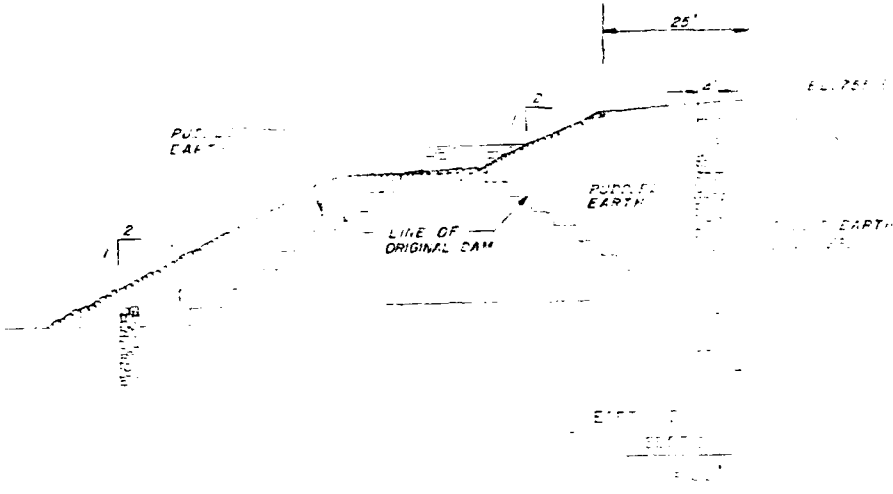


EMERGENCY SPILLWAY

ELEVATION

NOT TO SCALE

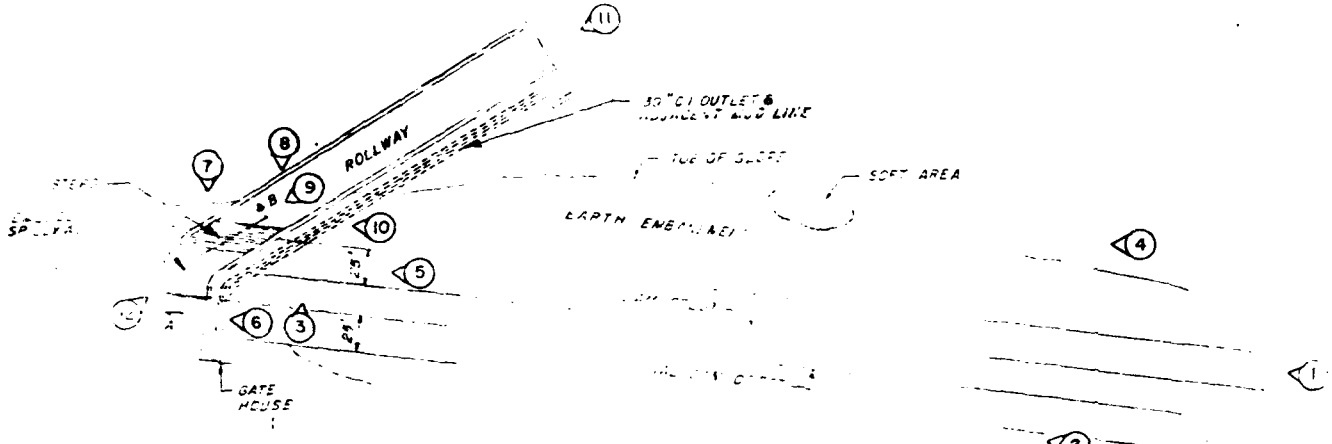
NATIONAL PROGRAM OF INSPECTION OF NON FEDERAL DAMS	
HOLDEN RESERVOIR NO. 1 DAM SECTION	
Holden, Massachusetts	Scale AS SHOWN

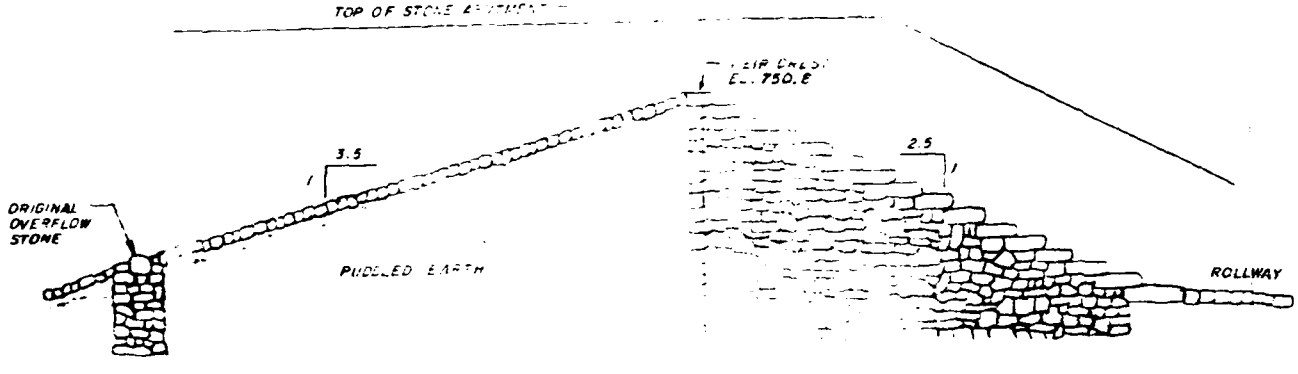


NATIONAL PROGRAM OF INSPECTION OF
NON FEDERAL DAM

HOLDEN RESER
SECTI

Holden, Massachuse





(1) NUMBER AND ORIENTATION OF PHOTGRAPH AS IN APPENDIX C

NATIONAL PROGRAM OF INSPECTION OF NON-FEDERAL DAMS
HOLTE
PLAN & SECT

Available Engineering Data

The plan of the reservoir and dam was obtained from the City of Worcester, Water Operations, 16 East Worcester Street, Worcester, Massachusetts 01604. The drawing is dated January 19, 1892 and traced February 27, 1936.

APPENDIX B

ENGINEERING DATA

APPENDIX D

HYDROLOGIC AND HYDRAULIC COMPUTATIONS


DRAINAGE AREA
HOLDEN RESERVOIR NO.1 DAM
IMPACT AREA
NATIONAL PROGRAM OF INSPECTION OF
NON FEDERAL DAMS
HOLDEN RESERVOIR NO 1 DAM
DRAINAGE AREA AND IMPACT AREA

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Consulting Engineers
210 South Street
BOSTON, MASSACHUSETTS 02111
(617) 423-5541

JOB HOLDEN RES. NO. 1
SHEET NO. 1 OF 12
CALCULATED BY GUS S. DATE 25 FEB 81
CHECKED BY [illegible] DATE 3-31-81
SCALE

TEST FLOOD ANALYSIS

Choose spillway design flood (SDF)

Classification – Size : Intermediate
Hazard : High

Use PMF as spillway design flood

From PMF guide curves for rolling terrain:
for DA = 4.7 mi^2 ...

Q_{P_1} = 1875 csm

Q_{P_1} = 1875 (4.7) = 8812.5, say 8800 cfs

Surcharge Storage Routing

$$Q_{P_2} = Q_{P_1} - Q_{P_1}\left(\frac{STOR}{19}\right)$$

ELEV. (FT)	SURCHARGE* STOR. (AC-FT)	STORAGE (IN)	Q_{P_2} (CFS)
752.3	200	0.80	8429
753.7	400	1.60	8059
755.2	600	2.39	7693
756.8	800	3.19	7323
758.2	1000	3.99	6952
759.5	1200	4.79	6581

See surcharge storage routing curve, SH 3/12.

* Refer to stage vs. surcharge storage curve, SH 4/12

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SHEET NO. 2 OF 12
CALCULATED BY GUS S. DATE 25 FEB 81
CHECKED BY HS DATE 3-31-81
SCALE

Develop discharge rating curve @ dam...

Use weir* equation, $Q = CLH^{3/2}$

C for emergency spillway = 3.7
dam embankment = 2.7

ELEV. (FT)	$Q_{SPILLWAY}$ (CFS)	Q_{EMBKMT} (CFS)	Q_{TOTAL} (CFS)
752.0	209		209
753.0	519		519
754.0	911		911
755.0	1369		1369
756.0	2061		2061
757.0	2456	2573	5029
758.0	3074	6421	9495

See rating curve @ dam, SH 3/12

From intersection of rating curve and surcharge storage routing curve:

outflow = 7150 c/s

elevation = 757.5

Dam embankment would be overtopped by 1.7 feet.

* See weir elevation, SH 5/12.

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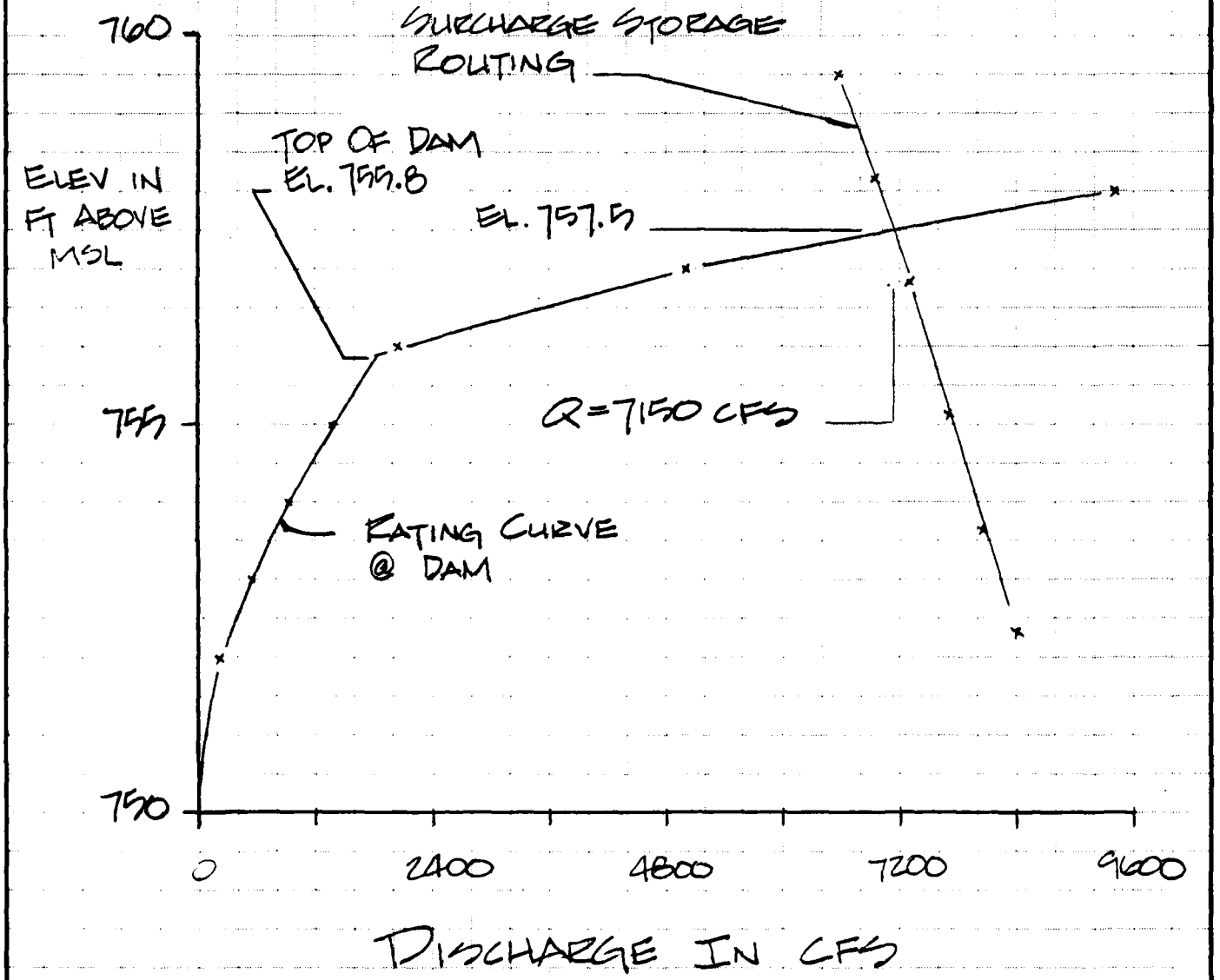
SHEET NO. 3 OF 12
CALCULATED BY GUS S. DATE 25 FEB 91
CHECKED BY HS DATE 3-31-91
SCALE

HOLDEN RESERVOIR NO. 1

STAGE VS. DISCHARGE



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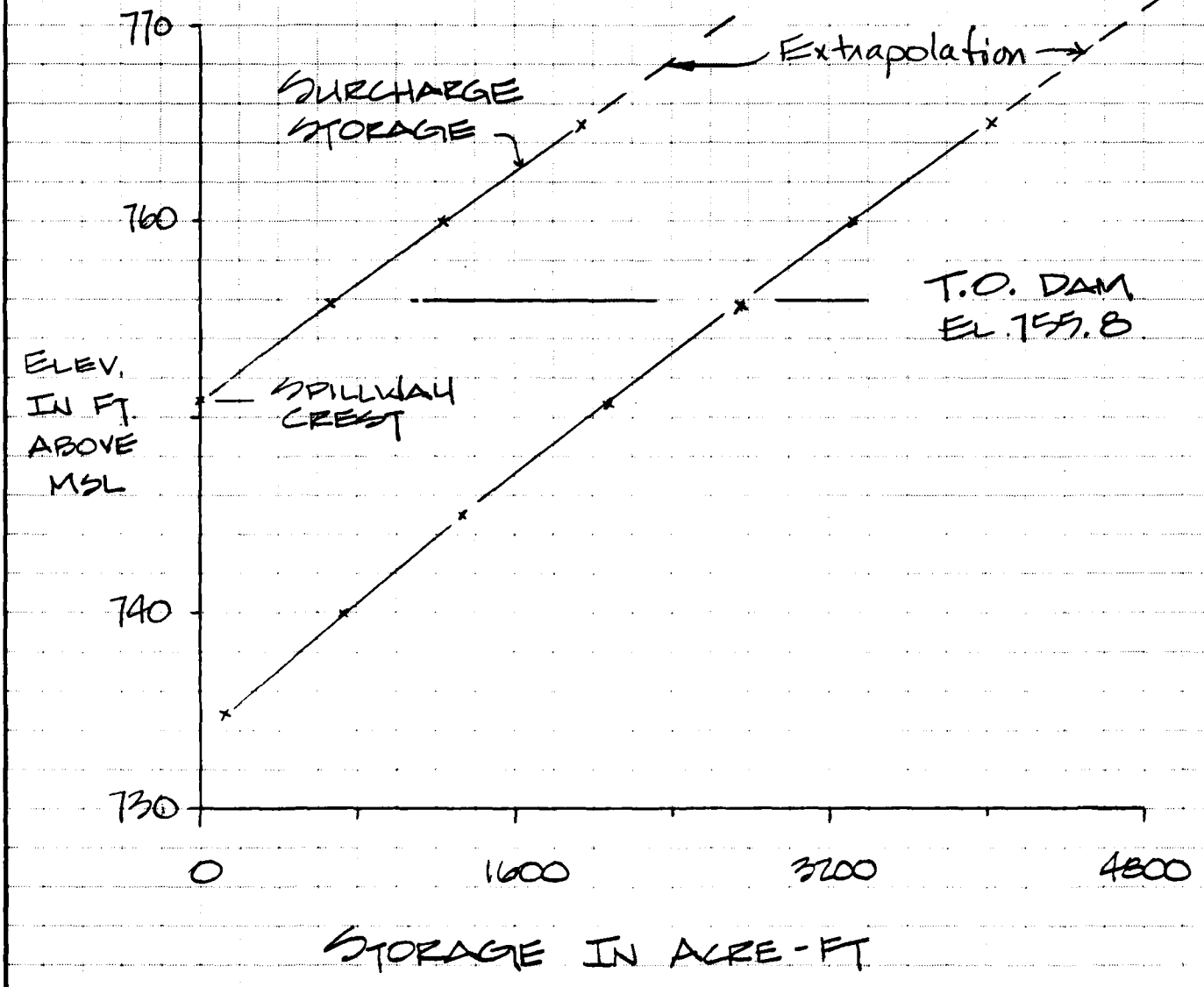
JOB HOLDEN RES. NO. 1
SHEET NO. 4 OF 12
CALCULATED BY GUS S. DATE 25 FEB 91
CHECKED BY H.S. DATE 3-3-91
SCALE

HOLDEN RESERVOIR NO. 1

STAGE VS. STORAGE



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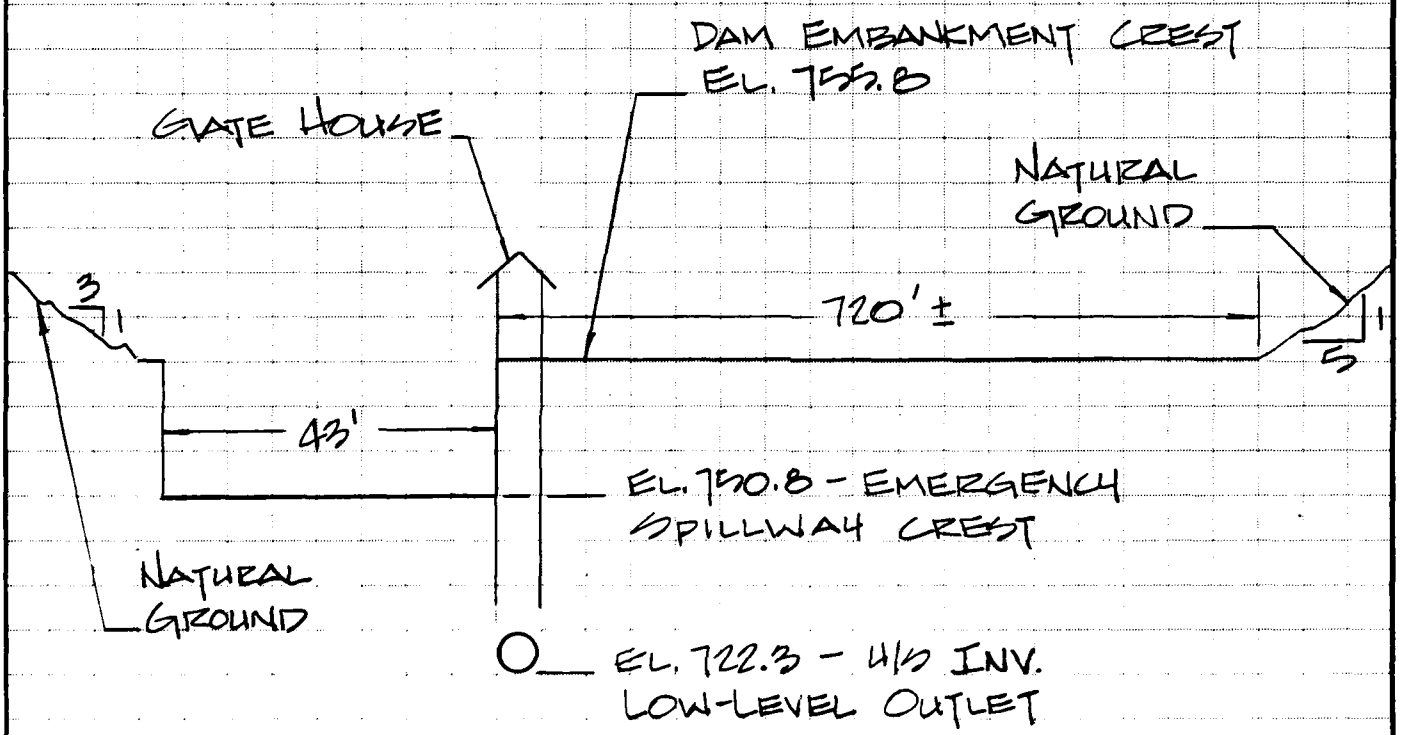
JOB HOLDEN RES. NO. 1
SHEET NO. 5 OF 12
CALCULATED BY GLKS DATE 26 FEB 81
CHECKED BY [illegible] DATE 3-31-81
SCALE

HOLDEN RESERVOIR NO. 1

WEIR ELEVATION

LOOKING DOWNSTREAM



NOTE: NATURAL GROUND SIDESLOPES GIVEN ARE AVERAGE VALUES.

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JOB HOLDEN RES. NO. 1
SHEET NO. 6 OF 12
CALCULATED BY GUS S. DATE 2 MAR 81
CHECKED BY H.S. DATE 3-31-81
SCALE

BREACH ANALYSIS

Breach flow @ dam, $Q_{P_1} = 8/27\ W_b \sqrt{g}\ 4_o^{3/2}$

Use $W_b = 180$ ft.
$4_o = 30$ ft.

$Q_{P_1} = 8/27\ (180)\ \sqrt{32.2}\ (30)^{3/2} = 49{,}729$, say 50,000 cfs

Reach 1

Downstream limit is the dam at Holden Reservoir No. 2.

Holden Reservoir No. 2 data:

Surface area ≐ 52.6 ac
Spillway weir is 50 ft wide x 6 ft deep
Crest of earth embankment ≈ 450 ft long

Develop rating curve for Holden No. 2 dam assuming insignificant flow through low-level outlet.

Use weir equation, $Q = CLH^{3/2}$
$C = 3.7$ for spillway, 2.7 for embankment

See SH 7/12 for rating curve for dam at Holden Reservoir No. 2.

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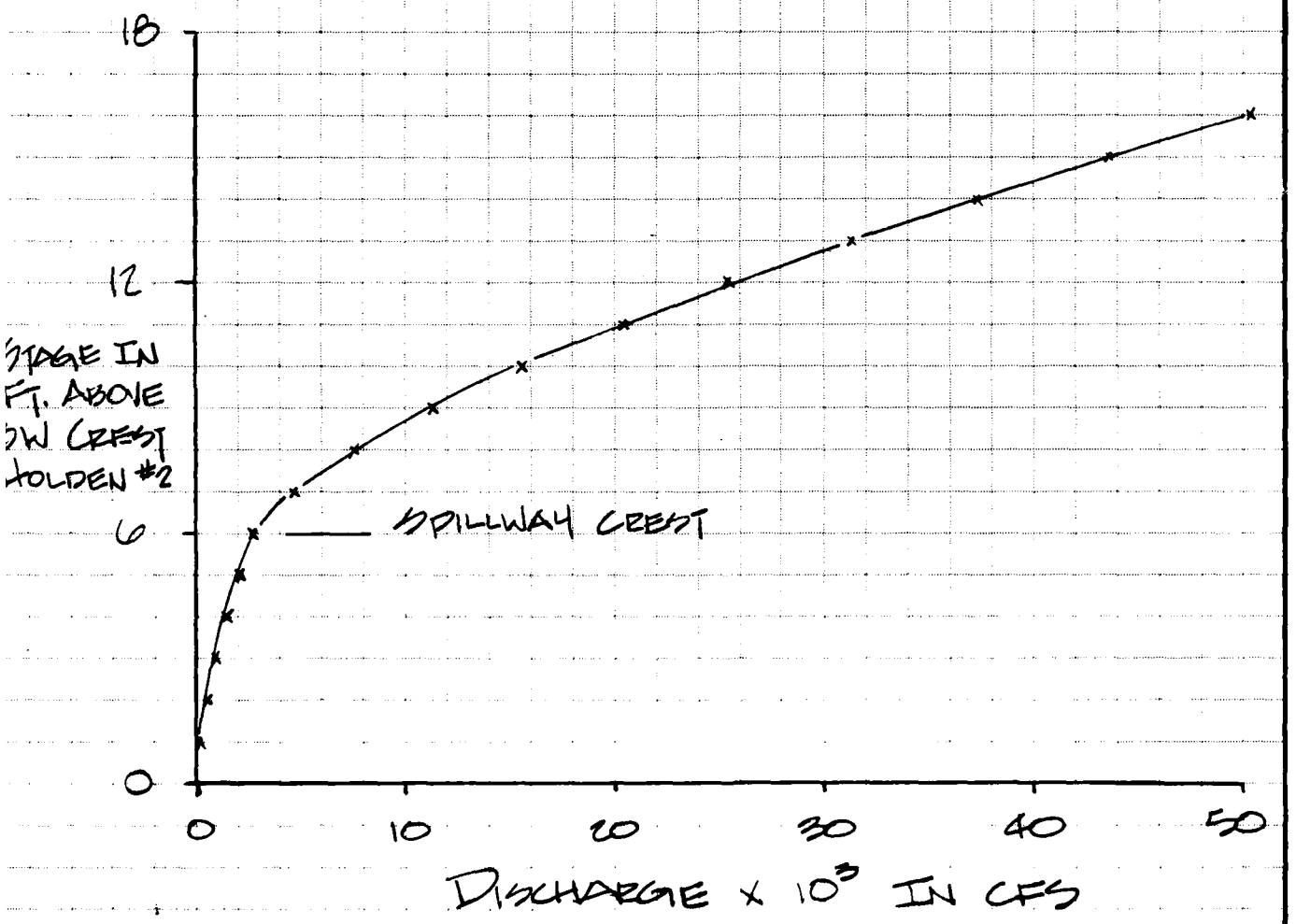
(617) 423-5541

JOB HOLDEN RES. NO. 1
SHEET NO. 7 OF 12
CALCULATED BY GWS DATE 2MAR81
CHECKED BY HS DATE 3-31-81
SCALE

BREACH ANALYSIS
REACH NO 1

STAGE VS. DISCHARGE
HOLDEN RES. NO. 2



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JOB HOLDEN RES. NO. 1
SHEET NO. 8 OF 12
CALCULATED BY GJS DATE 2 MAR 81
CHECKED BY HJS DATE 3-31-81
SCALE

BREACH ANALYSIS (cont.)

REACH 1 (cont)

$Q_{P_1} = 50000$ cfs

From rating curve for Holden No. 2, stage = 16 ft.

Area of water surface @ stage = 16 ft ≈ 78 ac.
@ stage = 0 ft ≈ 53 ac

$V_1 = 78\left(\frac{16}{2}\right) + 53\left(\frac{16}{2}\right) = 1048$ ac-ft $< \frac{2750^*}{2}$ ∴ OK

$Q_{P_2\,(TRIAL)} = Q_{P_1}\left(1 - \frac{V_1}{S}\right) = 50000\left(1 - \frac{1048}{2750}\right) = 30945$ cfs

From SH 7/12, stage = 12.9 ft.

$V_2 = 73\left(\frac{12.9}{2}\right) + 53\left(\frac{12.9}{2}\right) = 819$ ac-ft

$V_{AVG} = \frac{1048 + 819}{2} = 933.5$ ac-ft

$Q_{P_2} = 50000\left(1 - \frac{933.5}{2750}\right) = \underline{\underline{33027}}$ cfs

stage = 13.3 ft above spillway crest or 7.3 ft above T.O. dam; excessive damage to the earth embankment at Holden No. 2 would be expected.

* Storage @ T.O. dam, Holden Res. No. 1

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JOB HOLDEN RES. NO. 1
SHEET NO. 9 OF 12
CALCULATED BY GUS S. DATE 2 MAR 81
CHECKED BY HJ. DATE 3-31-81
SCALE

BREACH ANALYSIS (cont.)

REACH 2

Downstream limit is Dawson Rd., neglect Fisher Rd. immediately downstream of Holden Reservoir No. 2., length = 2800 ft

Develop rating curve @ Dawson Rd. culvert, see cross section, SH. 11/12.

Use FHA HEC-5 charts to rate twin, 4' ϕ concrete culverts; assume inlet control. Treat roadway as a weir where $Q = CLH^{3/2}$; use $C = 2.6$

See SH. 12/12 for rating curve @ Dawson Rd.

$Q_{P_1} = 33027$ cfs

From rating curve, stage = 13.3 ft.

See SH. 11/12 for natural valley cross section

$$V_1 = \frac{LA}{43560} = \frac{2800\left[21.3(20) + (21.3)^2 1.5\right]}{43560} = 465 \text{ ac-ft} < \frac{2750}{2}$$

$$Q_{P_2\,(TRIAL)} = Q_{P_1}\left(1 - \frac{V_1}{5}\right) = 33027\left(1 - \frac{465}{2750}\right) = 27442 \text{ cfs}$$

stage = 12.2 ft.

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JOB HOLDEN RES. NO. 1
SHEET NO. 10 OF 12
CALCULATED BY GLS S. DATE 2MAR81
CHECKED BY [illegible] DATE 3-31-81
SCALE

BREACH ANALYSIS (cont)

REACH 2 (cont)

$$V_2 = 2800\left[\frac{20.2(20) + (20.2)^2 15}{43560}\right] = 419 \text{ ac. ft}$$

$$V_{AVG} = (465 + 419) \div 2 = 442 \text{ ac. ft}$$

$$Q_{P_2} = Q_{P_1}\left(1 - \frac{V_{AVG}}{5}\right) = 33027\left(1 - \frac{442}{2750}\right) = \underline{\underline{27719}} \text{ cfs}$$

stage = 12.4 ft over Dawson Rd.

This stage would result in flooding of five inhabited structures adjacent to Dawson Rd. Two of these structures could be inundated by up to ten feet of water. Excessive property damage and loss of life are possible.

Accordingly, Holden Reservoir No. 1 Dam has been classified as High Hazard.

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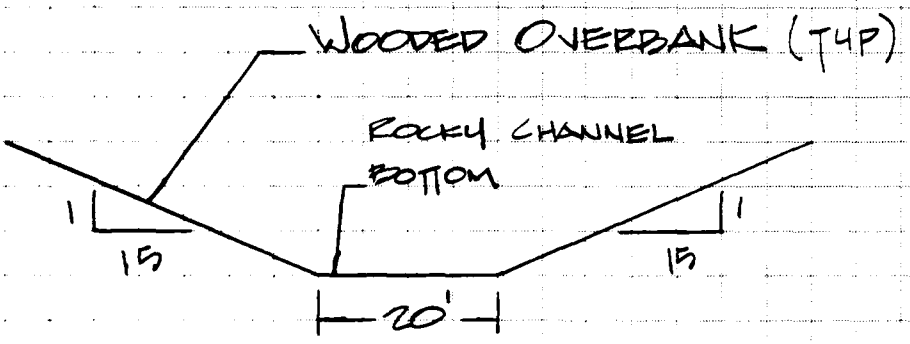
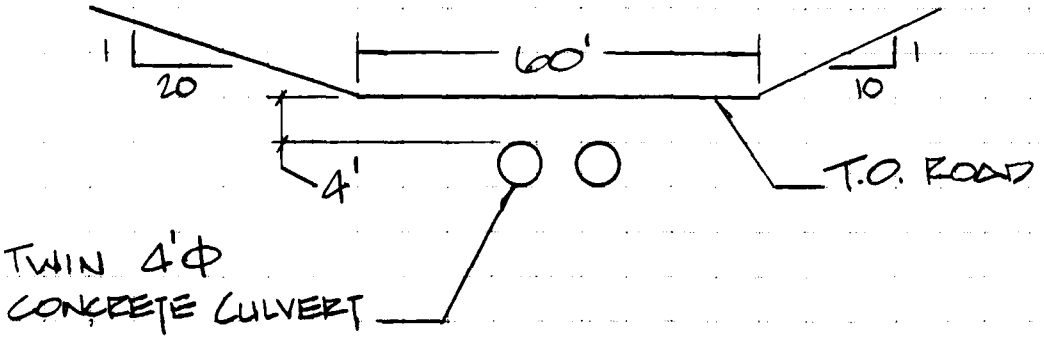
JOB HOLDEN RES. NO. 1
SHEET NO. 11 OF 12
CALCULATED BY GHS Sr. DATE 2 MAR 81
CHECKED BY DJ DATE 3-31-81
SCALE

BREACH ANALYSIS

D/S X-SECTIONS



REACH NO. 2
NATURAL VALLEY X-SECTION



REACH NO. 2
DAWSON RD. CULVERT
LOOKING DOWNSTREAM

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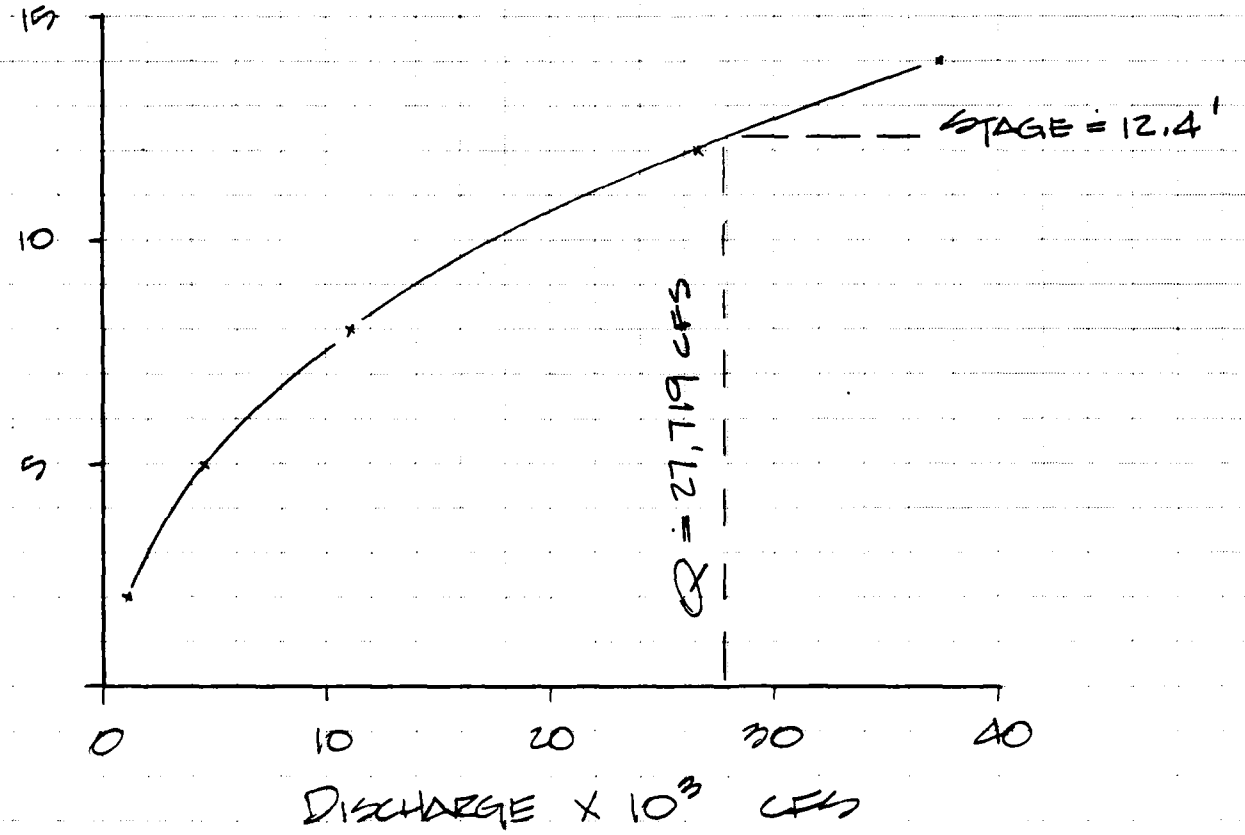
JOB HOLDEN RES. NO. 1
SHEET NO. 12 OF 12
CALCULATED BY GUS S. DATE 2 MAR 81
CHECKED BY DF DATE 3-31-81
SCALE

BREACH ANALYSIS

REACH NO. 2

DAWSON RD. CULVERT

STAGE VS. DISCHARGE



NOTE: Flow stages below top of road were not analyzed as they were judged insignificant to the matter at hand.

APPENDIX E

INFORMATION AS CONTAINED IN THE NATIONAL INVENTORY OF DAMS

NOT AVAILABLE AT THIS TIME

END

FILMED

8-85

DTIC